HIGH YIELD PULPING

ANNUAL PROGRAM REVIEW

SLIDE MATERIAL

MARCH 22, 1996

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TABLE OF CONTENTS

A G E N D A

High Yield Pulping PAC

8:00	Welcome	Earl Malcolm
8:30	Southern Pine Mechanical Pulping	Alan Rudie
9:15	Evaluation of Strain in Earlywood and Latewood of Loblolly Pine in Cyclic Compression	Cheryl Rueckert
9:45	Fundamentals of Brightness Reversion	Art Ragauskas
10:30	Break	

10:45	PAC Meeting (Advisory Committee Members Only)	
10:45	Introduction	Spencer Eachus
11:15	Southern Pine Mechanical Pulping	Alan Rudie
11:45	Fundamentals of Brightness Reversion	Art Ragauskas
12:15	Break and working lunch	
12:30	Project Proposals	Spencer Eachus

- Selection of one or more of the three preproposals for further development.
- Recommendation to RAC

1:30	New Project Discussions	Alan Rudie
2:00	Fall Meeting and other PAC Business	Spencer Eachus
2:30	Meeting Adjourns	

HIGH YIELD PULPING
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Revised 12/13/95:lkh

Project F012

Southern Pine Mechanical Pulping

Annual Project Review, March 22, 1996

Staff:

Alan Rudie
Alex Shaket
Blair Staley

Objectives:

- Improve the understanding of the performance limitations inherent in mechanical and chemimechanical pulping.
- The emphasis is on problem softwoods such as the southern yellow pines.

Background

- In 1993, Karen Hickey showed that energy was selectively absorbed by earlywood in cyclic compression of loblolly pine wooden blocks.
- Also in 1993, Jim St. Laurent demonstrated a slight enrichment of earlywood fibers in the small particle size fractions of TMP.

Goals

1. Evaluate changes in wood breakdown patterns for spruce and loblolly pine, concentrating on the early stages of refining.

2. Evaluate the role of earlywood and latewood in the breakdown of pine during refining.

3. Evaluate/confirm enrichment of earlywood in the small particle size fraction.

Experimental Procedure

All refining was carried out at the Andritz Sprout-Bauer Pilot Plant.

The first stage refiner was a 36-ICP pressurized refiner operating at 2000 RPM.

Second stage refining was carried out on a 36" Model 401 double disk atmospheric refiner.

Experimental

Refining was performed on plantation grown loblolly pine, natural stand loblolly pine and spruce.

Primary refining was carried out with normal refiner plates, plates with the fine bar section removed (Intermediate) and plates with the fine bar and half the intermediate bar sections removed (small).

Pulp Analysis

Second stage refined pulps were analyzed by Andritz Sprout-Bauer. The primary pulps were fractionated on a Bauer McNett using combinations of 4, 8, 14, 28, 48, 100 and 200 mesh screens.

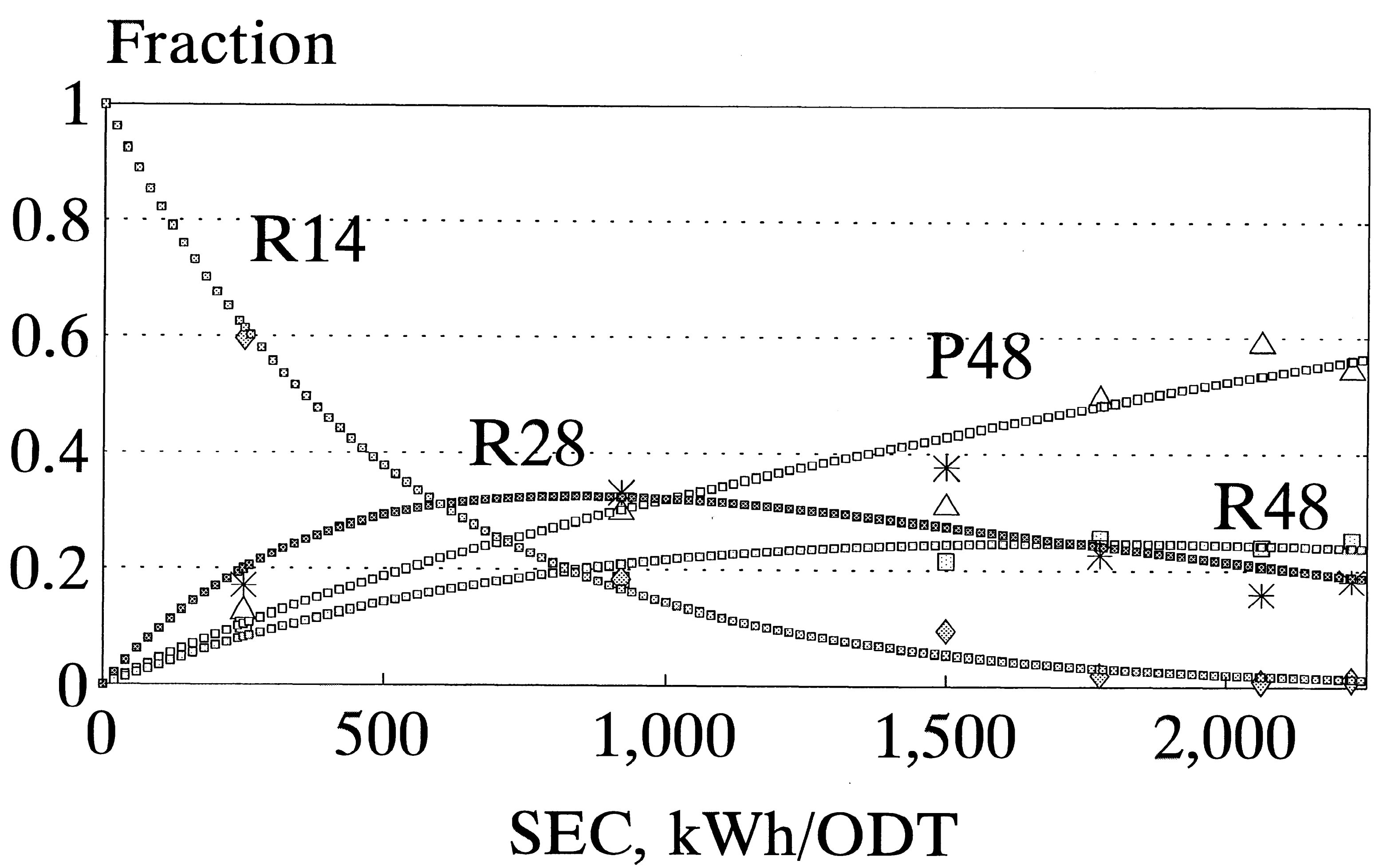
Screen fractions were delignified with sodium chlorite and disintegrated. The resulting pulp fiber length was measured using a Kajaani fiber length analyzer. Samples were checked by microscopy for EW/LW content and whole fibers.

Comminution Analysis

The Bauer McNett fractions were fit to a 4 fraction first order comminution model.

- k is the rate of decrease of R14
- k_1 is the rate of formation of R28
- k_2 is the rate of formation of R48
- k_3 is the rate of formation of P48
- k_4 is the rate R28 forms R48
- k_5 is the rate R48 forms P48.

Comminution model for the fast growth pine, using the whole refiner plates.

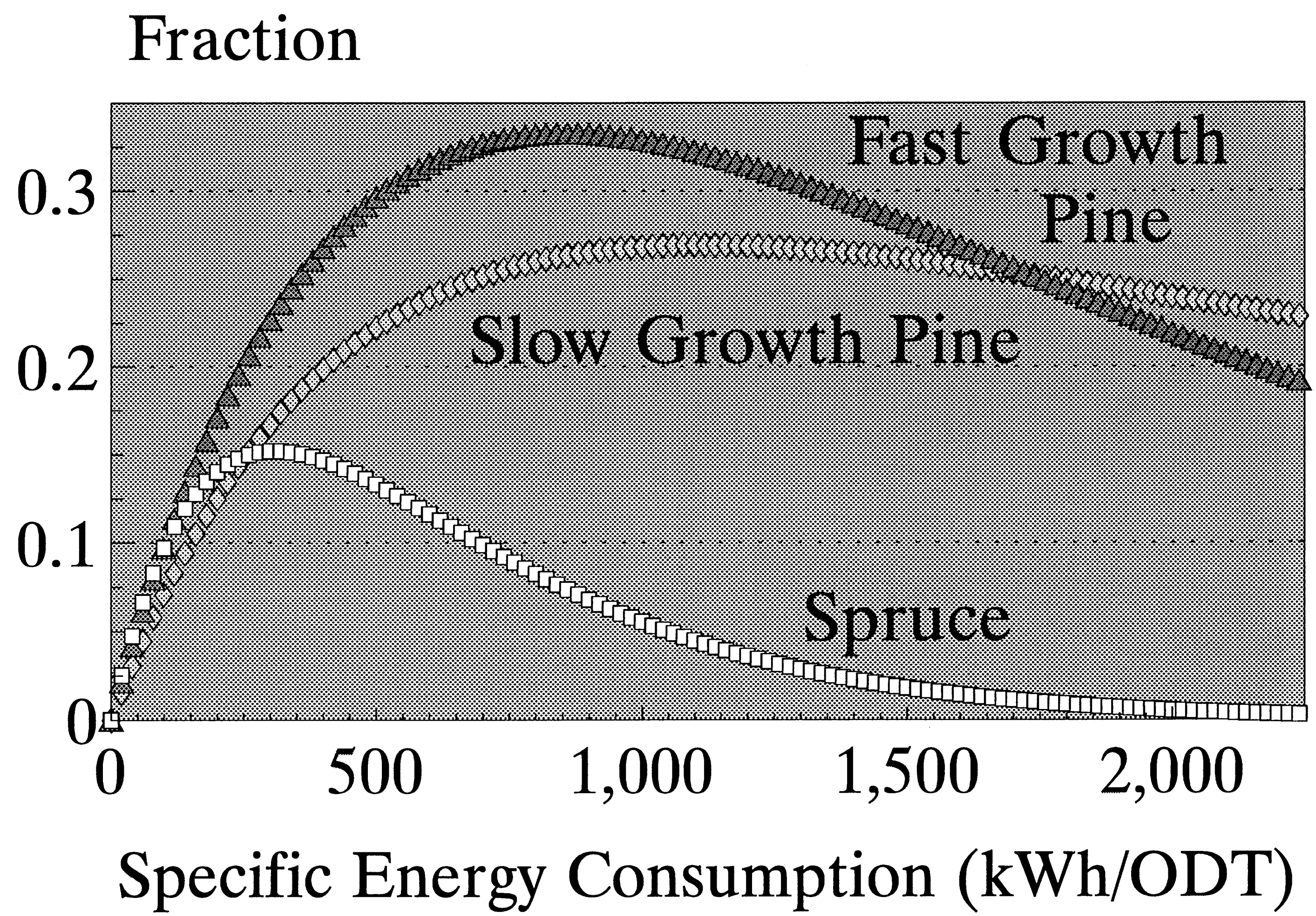


Comminution Constants

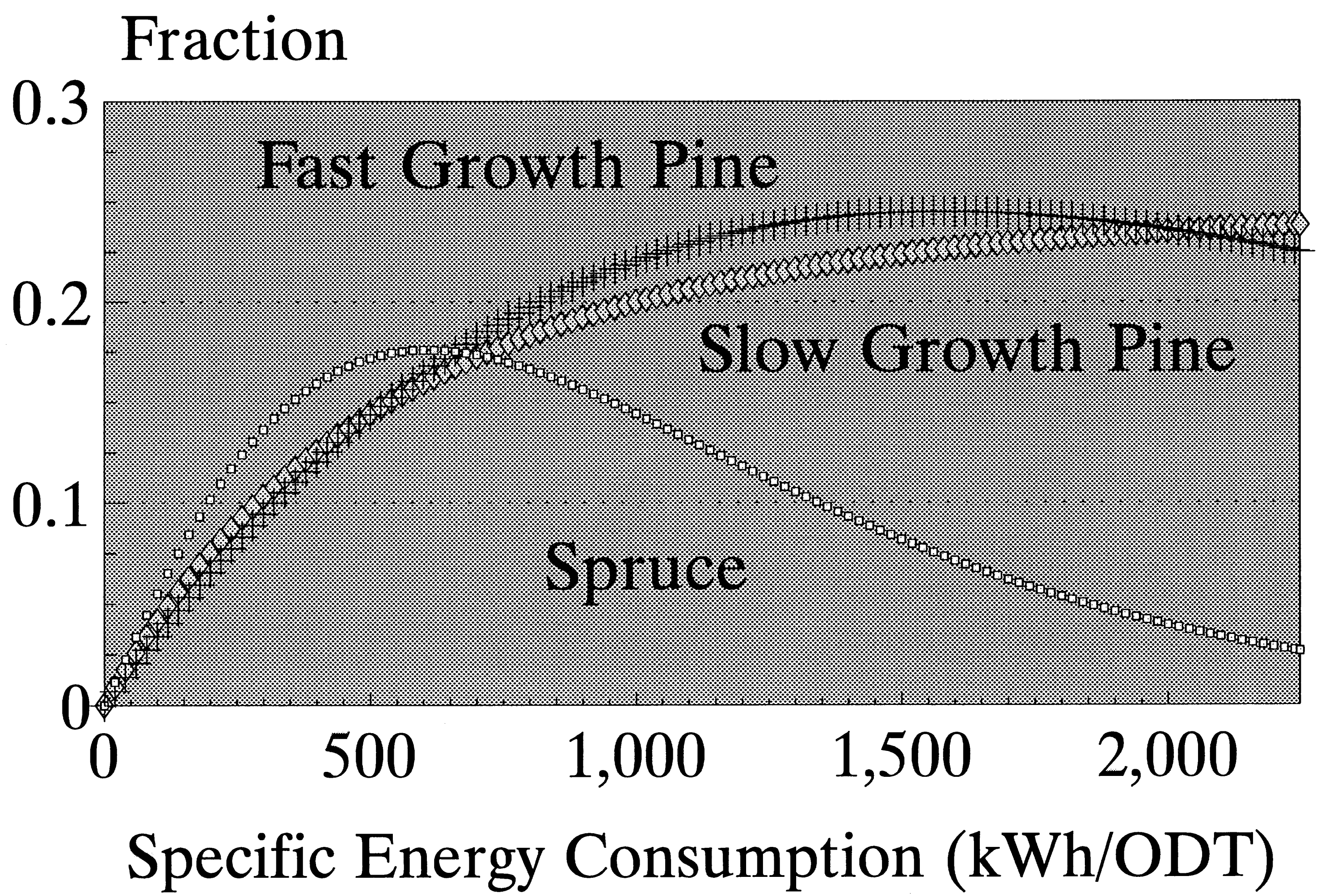
	k	k1	k2	k4	k5
Fast Full	0.186	0.11	0.035	0.067	0.082
Fast Int.	0.25	0.14	0.033	0.14	0.13
Slow Full	0.23	0.08	0.046	0.023	0.019
Slow Int.	0.25	0.095	0.058	0.067	0.076
Spr. Full	0.41	0.135	0.057	0.25	0.19
Spr. Int.	0.25	0.09	0.065	0.02	0.033

All values are x 10^{-2}

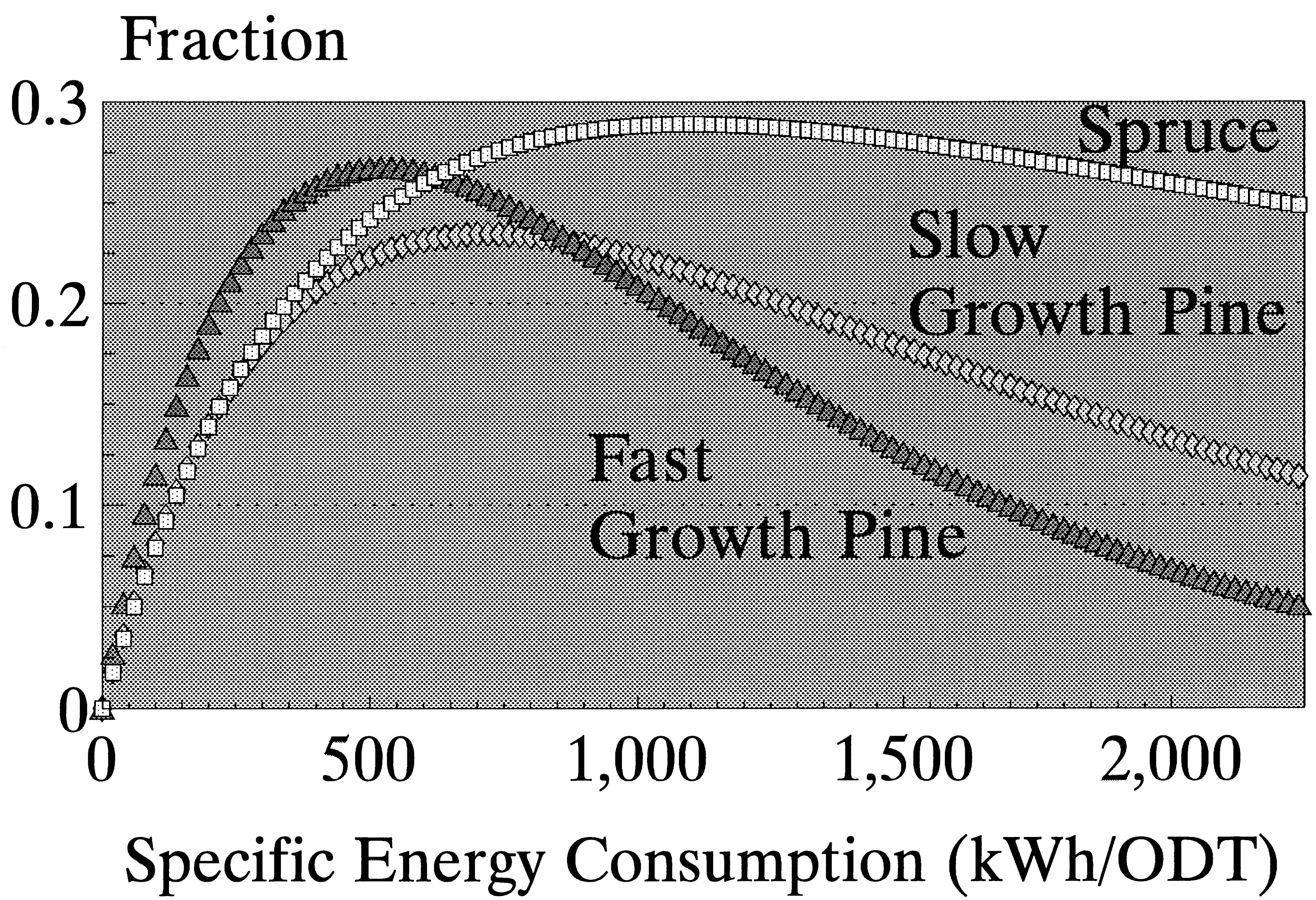
Changes in the R-28 Fraction
Full Refiner Plates



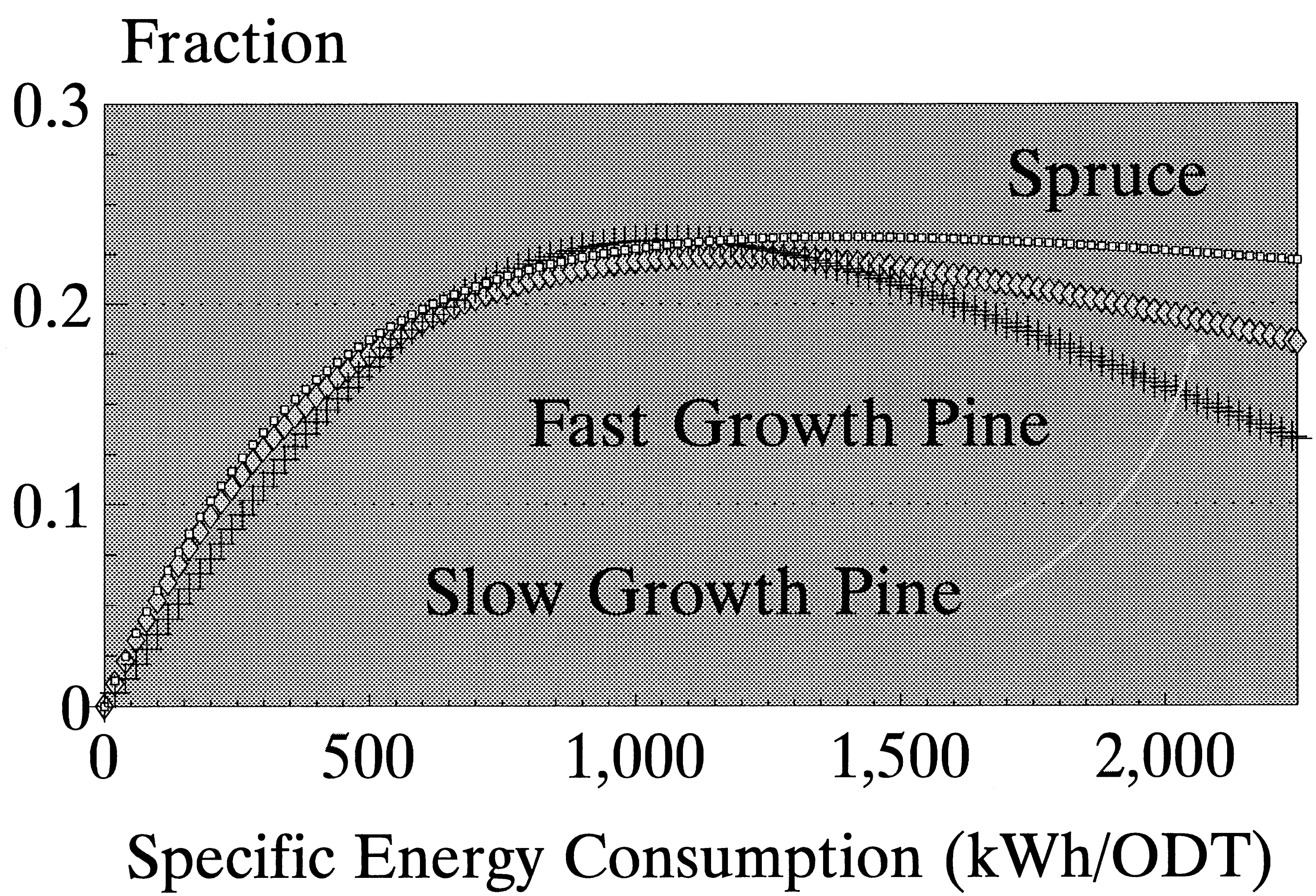
Changes in the R-48 Fraction
Whole Refiner Plates



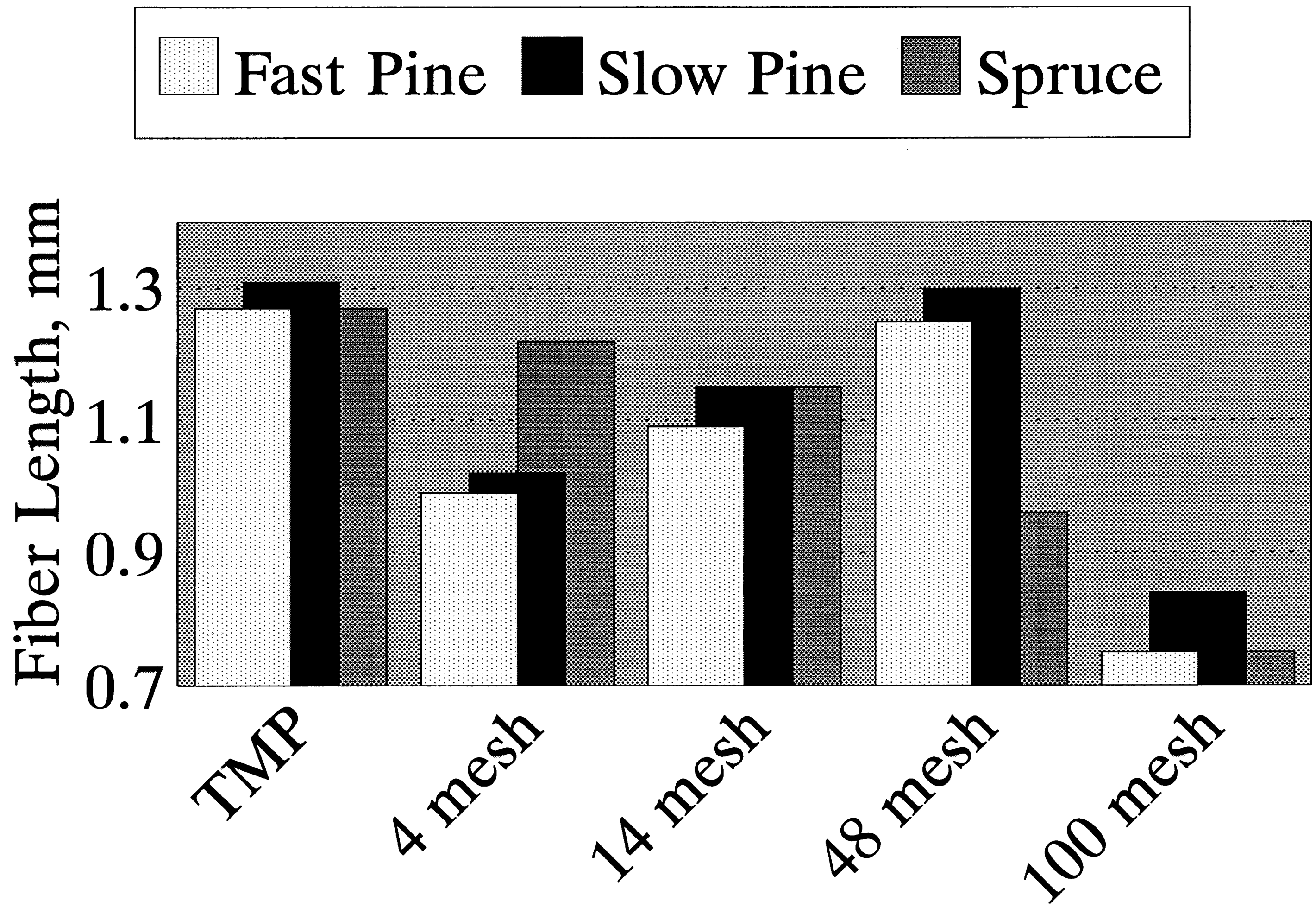
Changes in the R-28 Fraction
Intermediate Refiner Plates



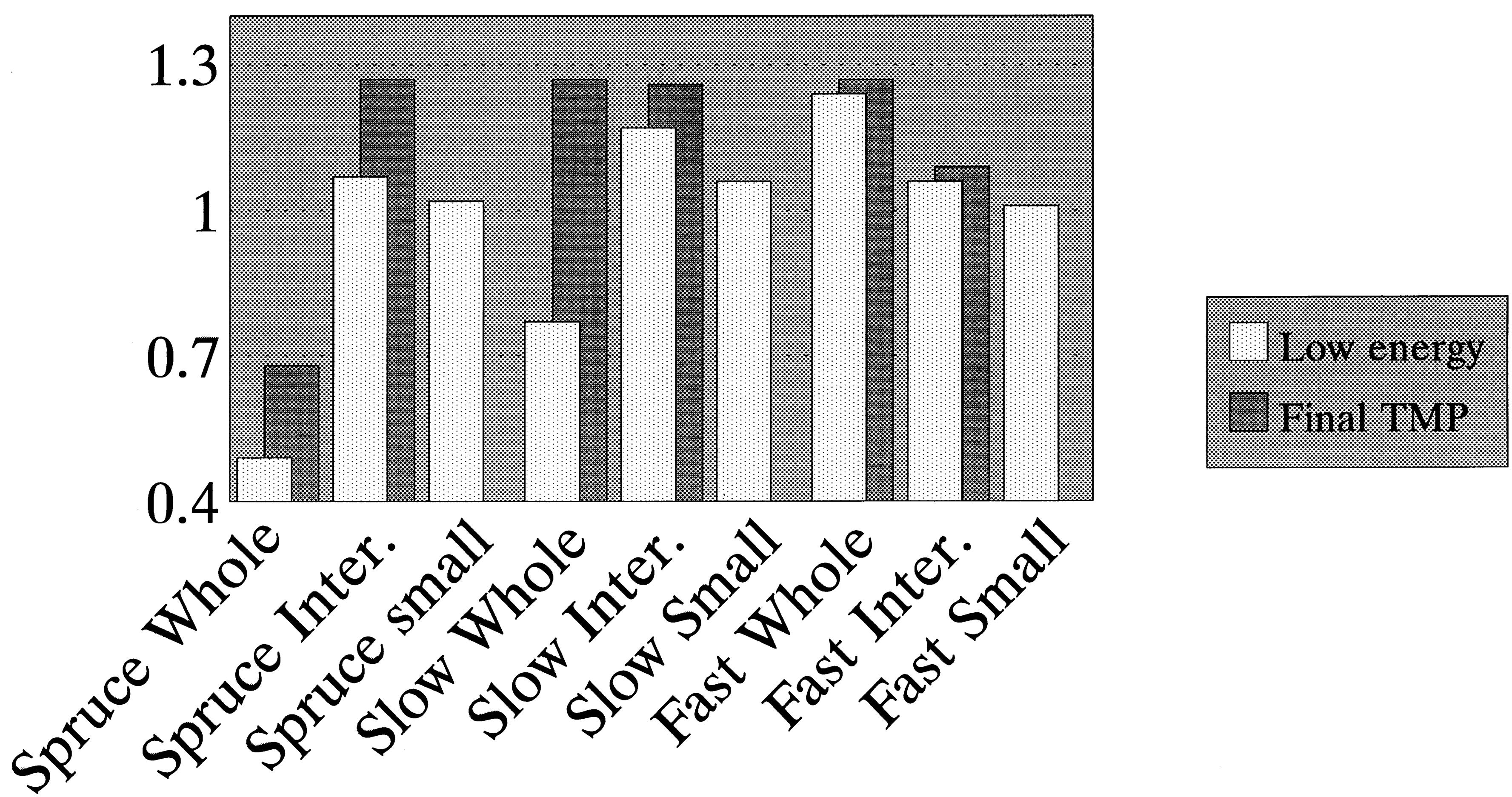
Changes in the R-48 Fraction
Intermediate Refiner Plates



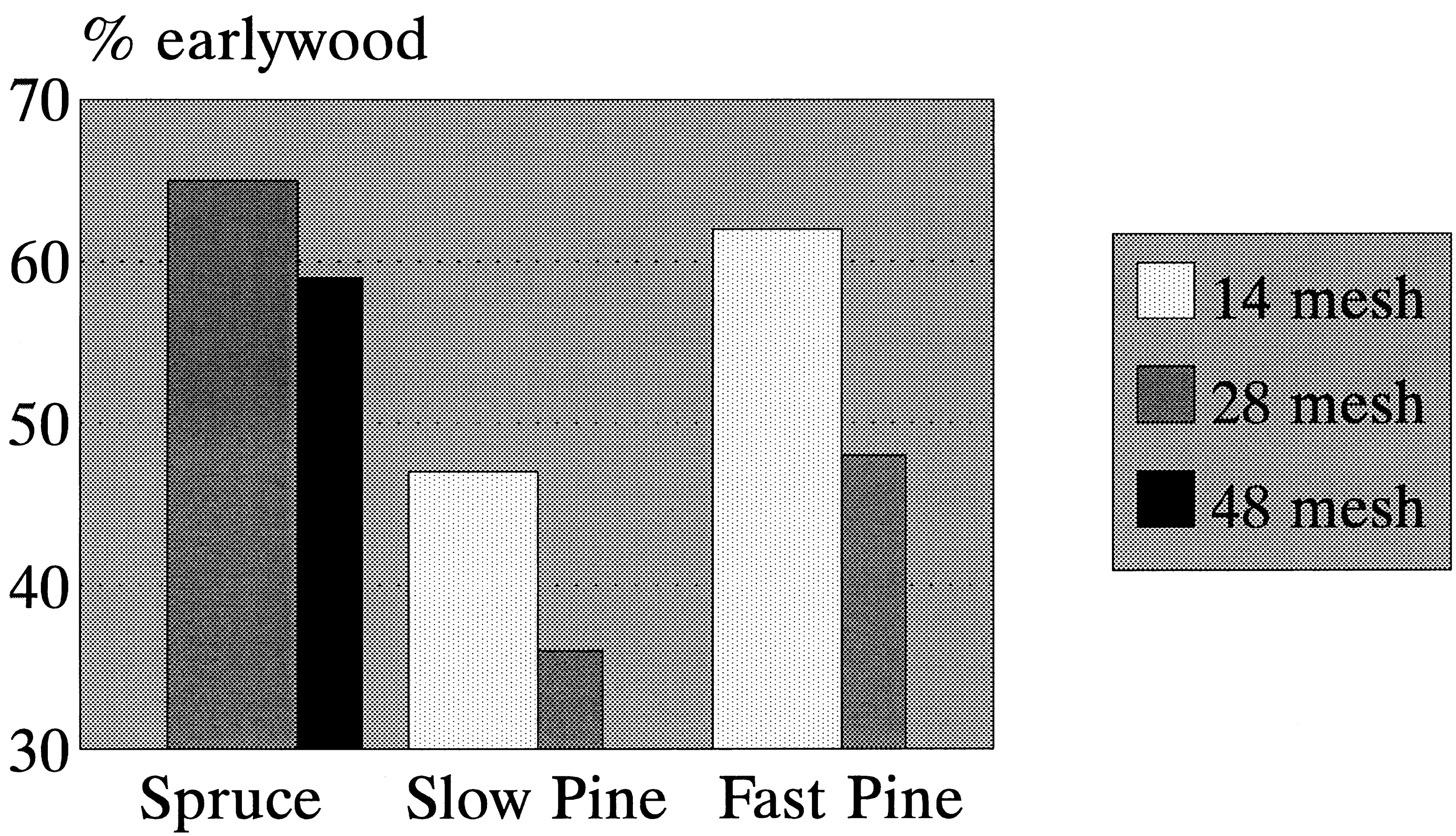
Fiber length of refined TMP and holopulped fractions



Estimated fiber length of low energy pulps relative to final pulps.



Earlywood Enrichment
Data from intermediate refiner plates



Conclusions

- All three wood types refine at about the same rate.
- Fast growth pine develops the R28 mesh fraction faster, but it also decays faster.
- Slow growth pine develops the R48 mesh fraction faster, but R28 and R48 decay at half the rate of fast grown pine.
- Spruce develops the R28 and R48 mesh at the same pace as slow growth pine, but they decay even slower.

Conclusions

- The fiber length of the coarse wood fractions is similar to fully refined pulp. Even at 200 kWh/ODT refining levels.
- Preliminary results on earlywood enrichment in the small particle fractions do not confirm the earlier findings.

Remaining Work

- Complete the optical microscopy on the chlorite holopulp samples.
- Evaluate the exposed surface of wood particles using the SEM.
- Possibly, look at even lower energies.

Acknowledgements:

Marc Sabourin and Andritz Sprout-Bauer

Newsprint South

The Member Companies of IPST

An Evaluation of Strain in Earlywood and Latewood Fibers During Cyclic Compression

C.B. Rueckert

March 1996

Mechanical Pulping PAC

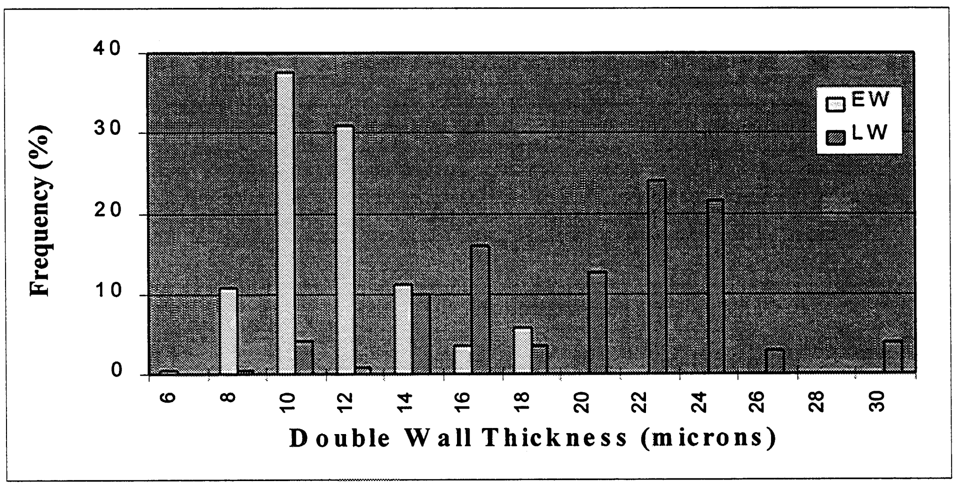
Outline

- Introduction
  - » Fiber Variability
- Cyclic Compression and Fatigue of Wood
  - » Wood Blocks
  - » Wood Particles
  - » Thesis Oljective
  - » Fiber Aggregates
    - – Experimental
    - – Discussion
- Conclusion
- Future Work

Introduction

- **Variability of Wood Fibers**
  - » **Anatomy**
    - – **cell wall thickness**
    - – **fiber length**
  - » **Mechanical Properties**

Bimodal Distribution of Fiber Wall Thickness in Loblolly Pine



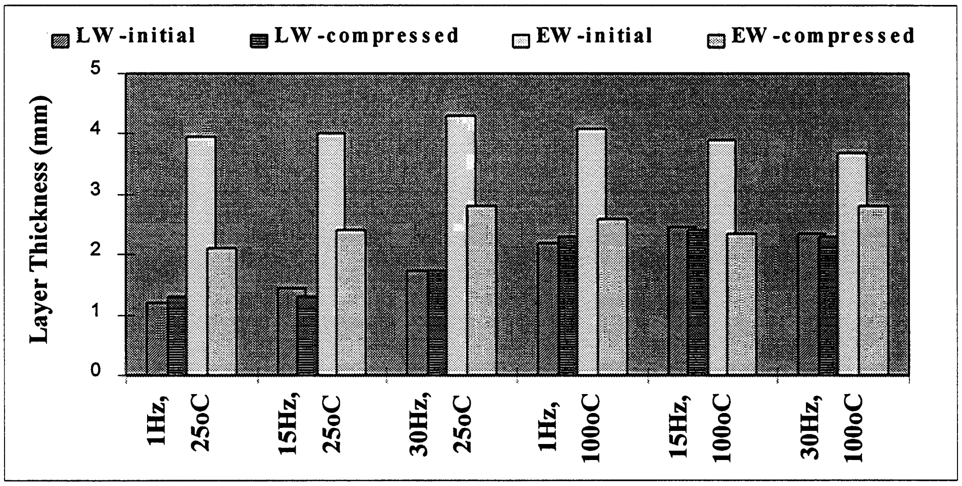
Wood Blocks

- **Salmen, Fellers, Tigerstrom**
  - » **greater fatigue with:**
    - – **lower frequency**
    - – **higher amplitude**
    - – **higher temperature**

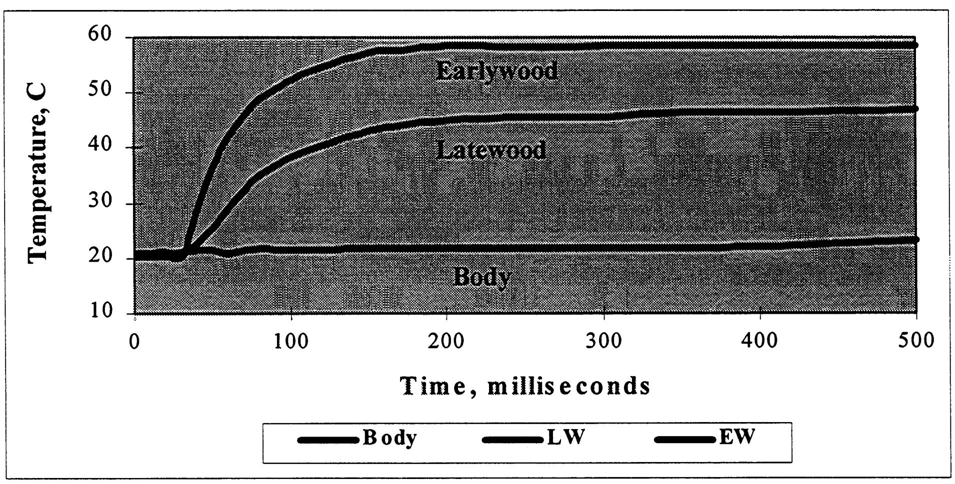
Wood Blocks (cont.)

- **IPST**
  - » **Earlywood and Latewood**
    - – **strain: width of growth zone change**
    - – **temperature: different temperature rise and temperature at equilibrium**
    - – **Preferential Energy Absorption by Earlywood?**

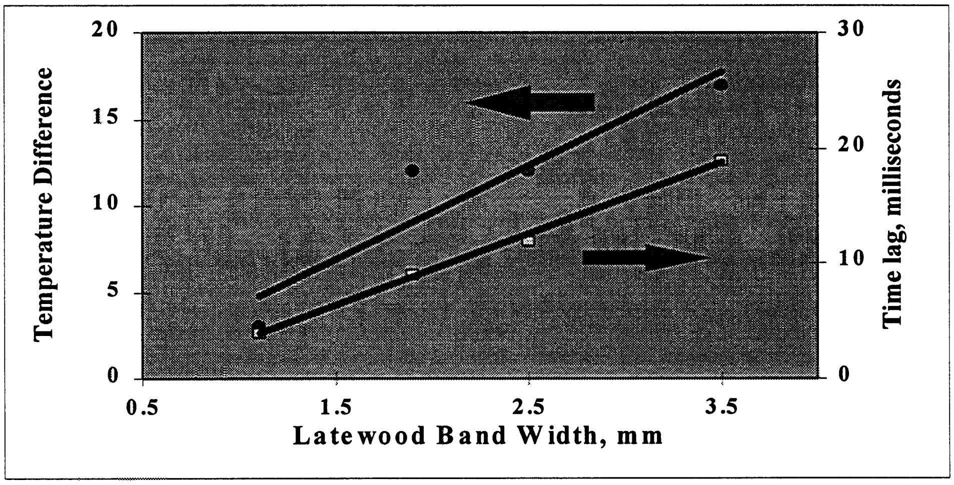
Response of Earlywood and Latewood to Cyclic Compression-10,000 Cycles



Temperature Record of Wood Block during Cyclic Compression



Equilibrium Temperature Difference Between Earlywood and Latewood



Wood Particles (cont.)

- **IPST**
  - » **Preferential Energy Absorption**
    - – **Earlywood breaks early in refining process**
    - – **Earlywood should be concentrated in small size fractions after low energy refining**

Wood Particles (cont.)

Sample of Mesh	Coarseness (mg/m)	Fiber Length (mm)
EW	0.16	2.80
LW	0.38	3.26
4	0.22	3.21
8	0.21	2.94
20	0.17	2.62
100	0.18	1.21

Thesis Objective

- **Investigate the distribution of strain between earlywood and latewood in fiber aggregates subjected to cyclic load to simulate a disk refiner. The working hypothesis is that the earlywood fibers will be preferentially strained and have a larger temperature increase than the latewood fibers.**

Fiber Aggregates - Experimental

- **Fiber Aggregates**
  - » **Experimental**
    - – Loblolly pine log, hand cut to make chips of pure earlywood or latewood
    - – chips were refined using low energy
    - – pulp was fractionated to find single fibers
      - 4, 14, 28, 48 mesh screens
      - fibers then pasteurized and placed in cold room for storage

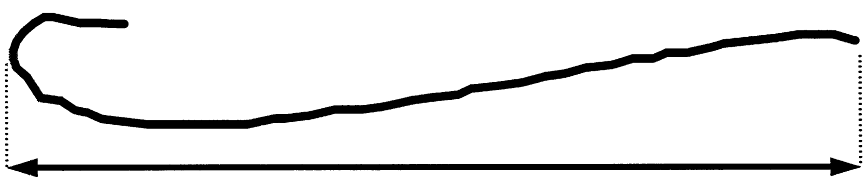
Fiber Aggregates - Experimental (cont.)

- **Experimental**
  - » **Fiber aggregate mass determined with 12" Sprout Waldron**
  - » **Fibers were mixed in a 50/50 ratio by mass of earlywood and latewood**
    - – before mixing 5% of either earlywood or latewood was stained with a fluorescent dye
    - – fibers mixed and brought to 30% consistency

Fiber Aggregates - Experimental (cont.)

- **Experimental**
  - » **Frequency of 10 Hz**
  - » **Double Amplitude of 1 mm**
  - » **Aggregates video taped undergoing 10,000 stroke compression sequence**
  - » **Curl index measured at 0, 1, 10, 100, 1000, 10,000 cycles and each half cycle following the indicated cycle except 0**

Curl Index Definition

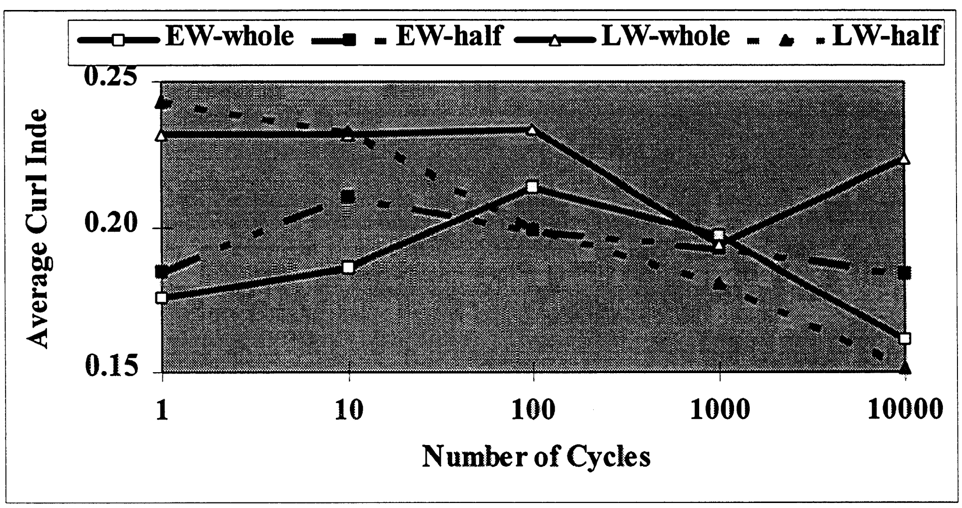


Curl Index = (fiber length / longest dimension) - 1

Yellow line = fiber length
White arrow line = longest dimension

Straight Fiber Curl Index = 0

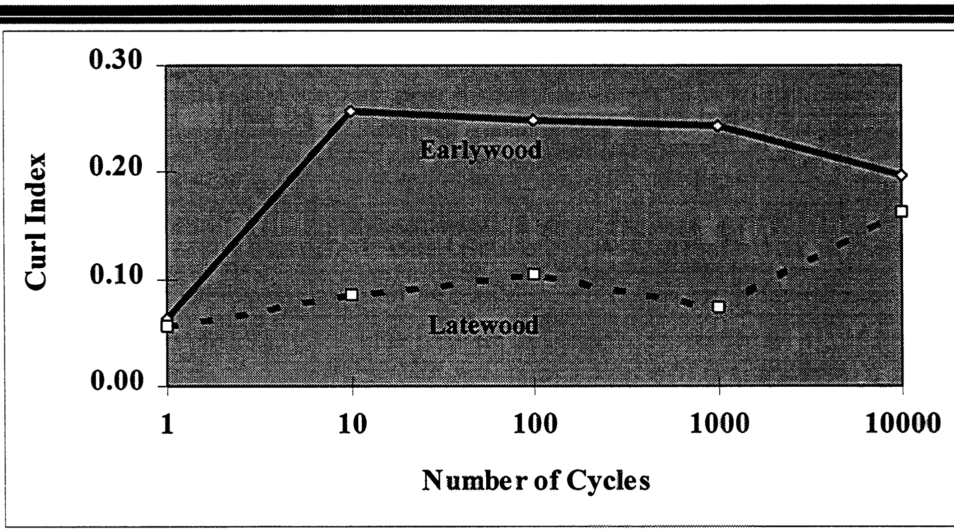
Average Values of Curl Index at 10 Hz



Strain Definition

Strain = Average | Curl Index $_{half}$ - Curl Index $_{whole}$ |

Average Absolute Values of Individual Fiber Differences in Curl Index



t-Test, Average Absolute Individual Fiber Difference ($\Delta EW = \Delta LW$)

Cycle	Fiber Type	Mean	# Observ.	Prob. 1-tailed	Prob. 2-tailed
|1.5-1|	EW	0.064	46	0.292	0.585
	LW	0.056	52		
|10.5-10|	EW	0.257	46	0.000	0.000
	LW	0.086	52		
|100.5-100|	EW	0.248	46	0.003	0.006
	LW	0.105	52		
|1000.5-1000|	EW	0.244	46	0.000	0.000
	LW	0.074	52		
|10,000.5-10,000|	EW	0.196	46	0.211	0.421
	LW	0.163	52		

Conclusion

- **Earlywood's curl index has a greater change with each compression compared to latewood at most of the measured cycles, leading to flexing and increases in fatigue rate.**

Future Work

- Thermal imaging
- Higher frequencies

Acknowledgments

- My thesis committee:
  - » Alan Rudie (advisor)
  - » Earl Malcolm
  - » Pierre Brodeur
- The Member Companies of IPST

Fundamentals of Brightness Stability
F014

Art J. Ragauskas

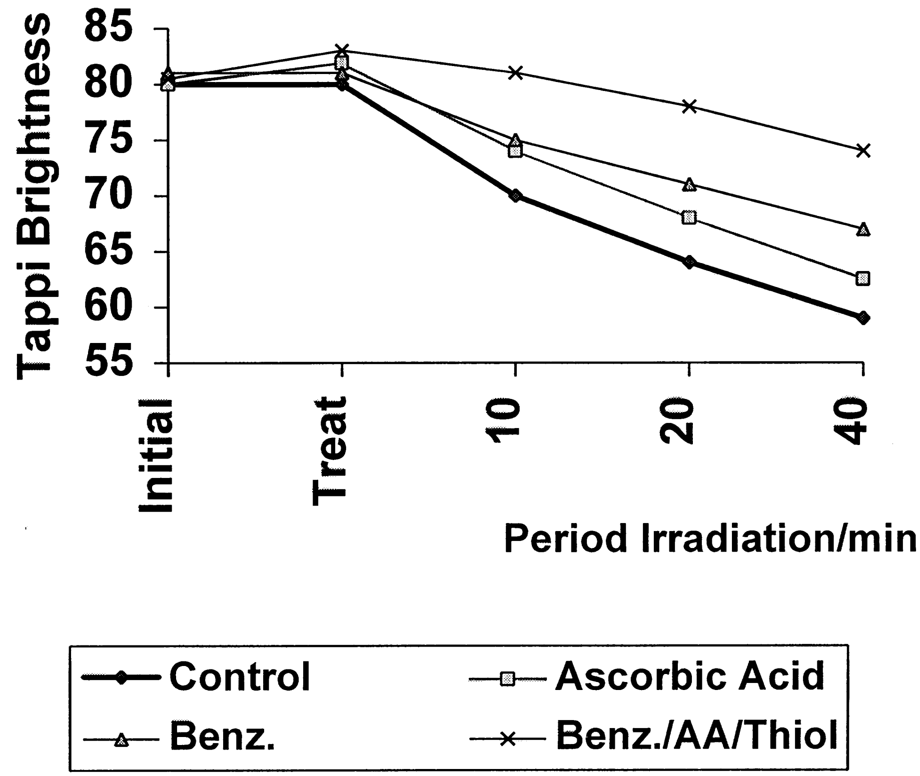
F014: Fundamentals of Brightness Stability

- **Research Objective:**
  - **Investigate mechanisms of brightness reversion**
  - **Develop photostabilization technologies**

- **Project Goal:**
  - **Increase the usefulness of high-yield fibers**

F014: Fundamentals of Brightness Stability - Past Accomplishments

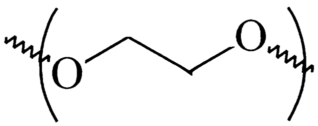
- **Research emphasis on photostabilization additives**
  - New agents: hexadienol, 5-pentadienoic acid
  - New application technologies



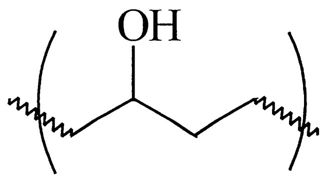
F014: Fundamentals of Brightness Stability FY 1995 -96 Goals

- **Examine photostabilization effects of:**
  - **Polymeric additives**
  - **Benzotriazaole derivatives**
  - **Additive mixtures**
- Examine factors contributing to photostabilization effect

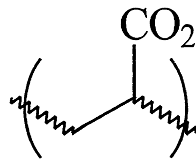
F014: Polymeric Additives Studied



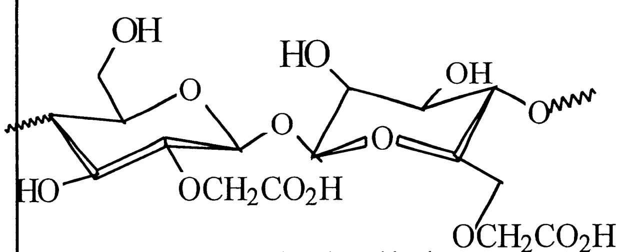
Polyethylene glycol



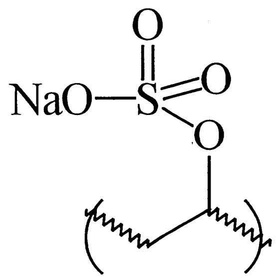
Polyvinyl alcohol



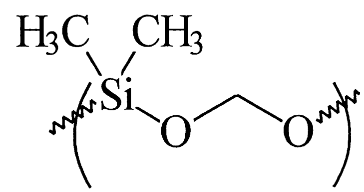
Polyacrylic acid



Carboxymethylcellulose



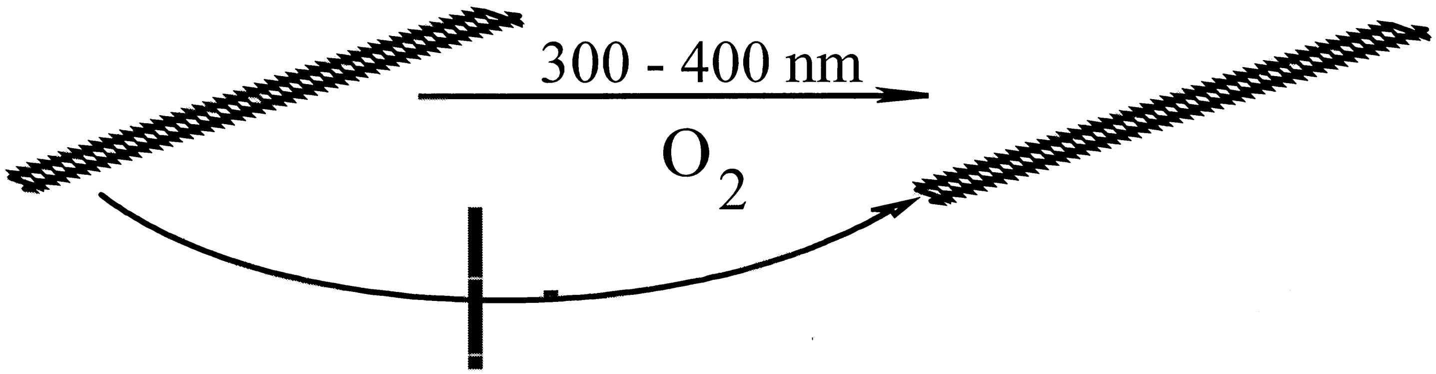
Polyvinylsulfate



Polydimethylsiloxane-coethylene oxide

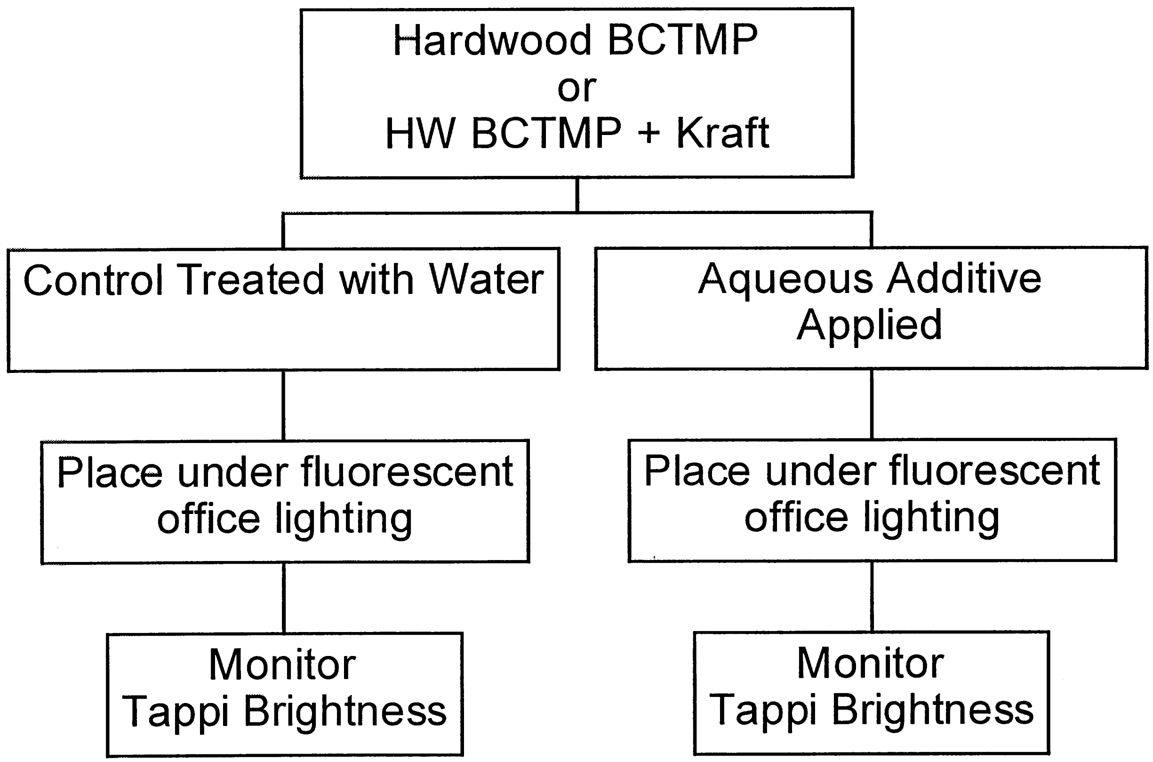
F014: Proposed Photostabilization Mechanism for Polymeric Additives

- Fact
  - Brightness reversion requires O_2

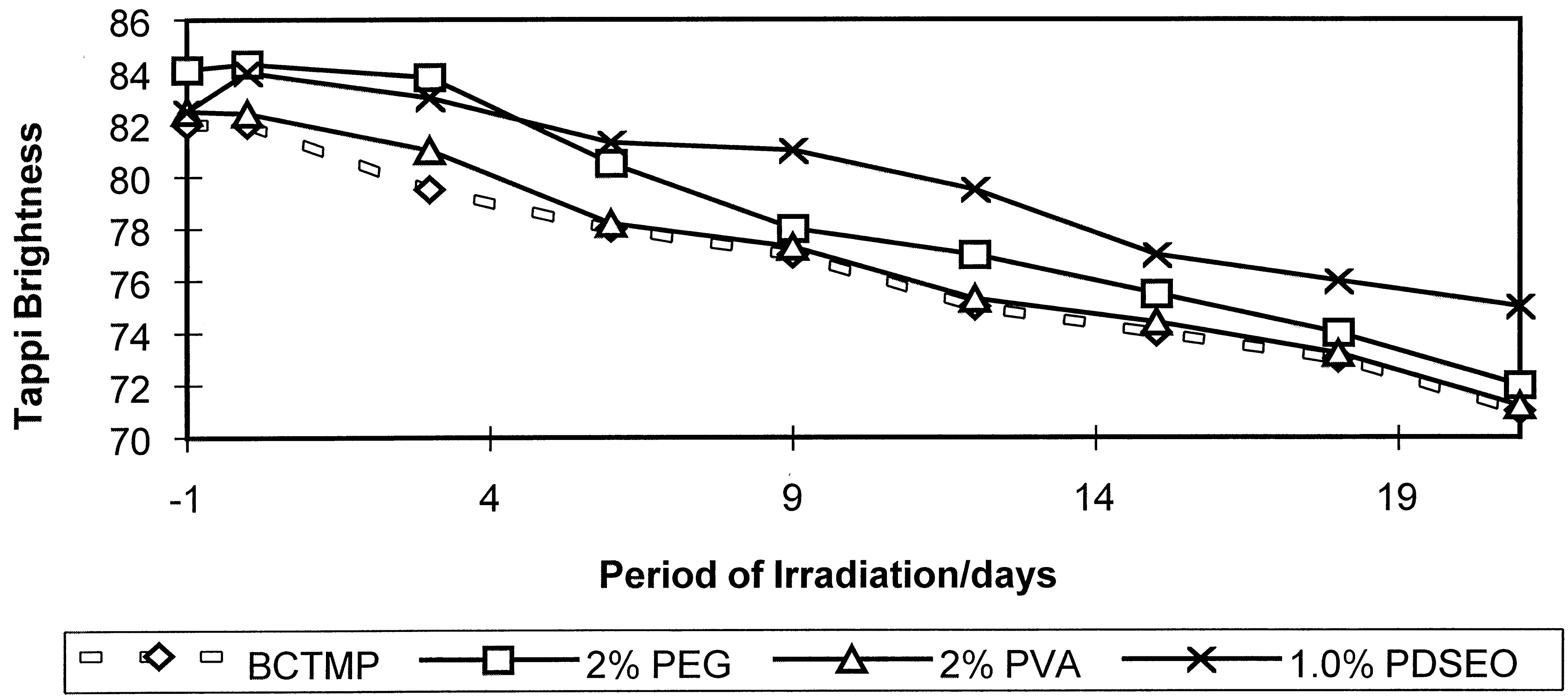


  - Polymeric additives could behave as O_2-barriers

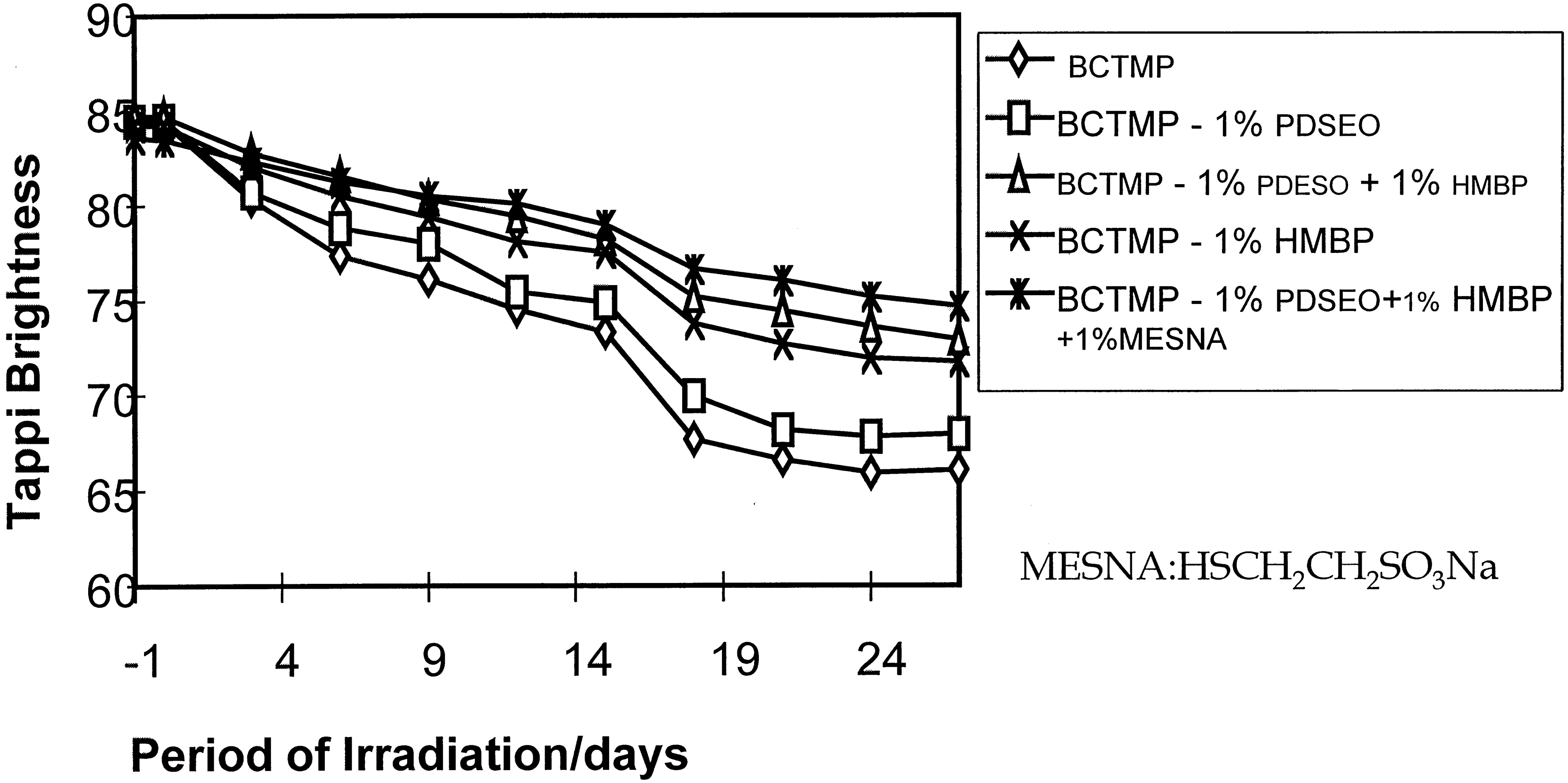
F014: General Experimental Method



F014: Photostabilization Effects for Polymeric Additives



F014: Photostabilization Effects for Polymeric Additives



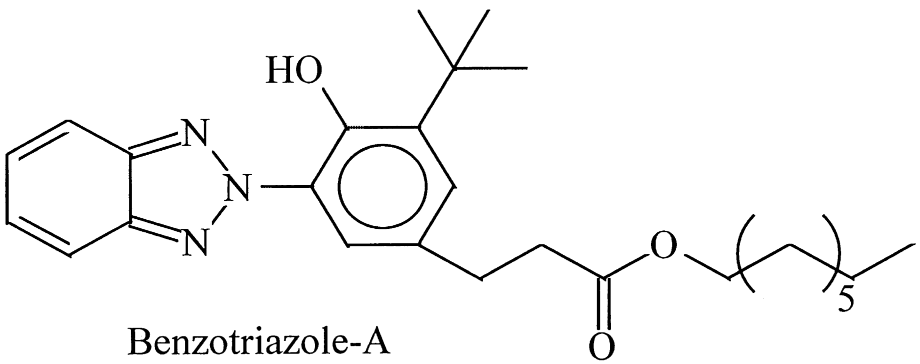
MESNA: $HSCH_2CH_2SO_3Na$

F014: Photostabilization Effects for Polymeric Additives - Summary

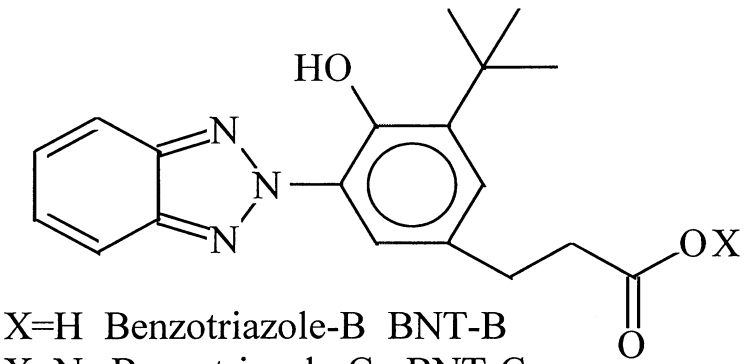
- **PDSEO was only polymeric additive with modest photostabilization effect employing 1 - 2% charge**

- **Polymeric additives presumably failed due to insufficient application levels.**

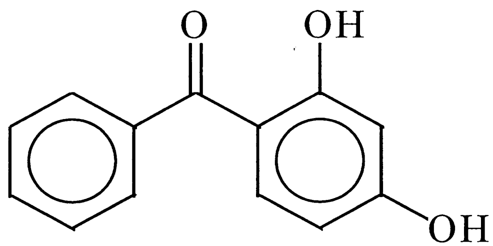
F014: Photostabilization Effects for Benzotriazole Derivatives



Benzotriazole-A
BNT-A

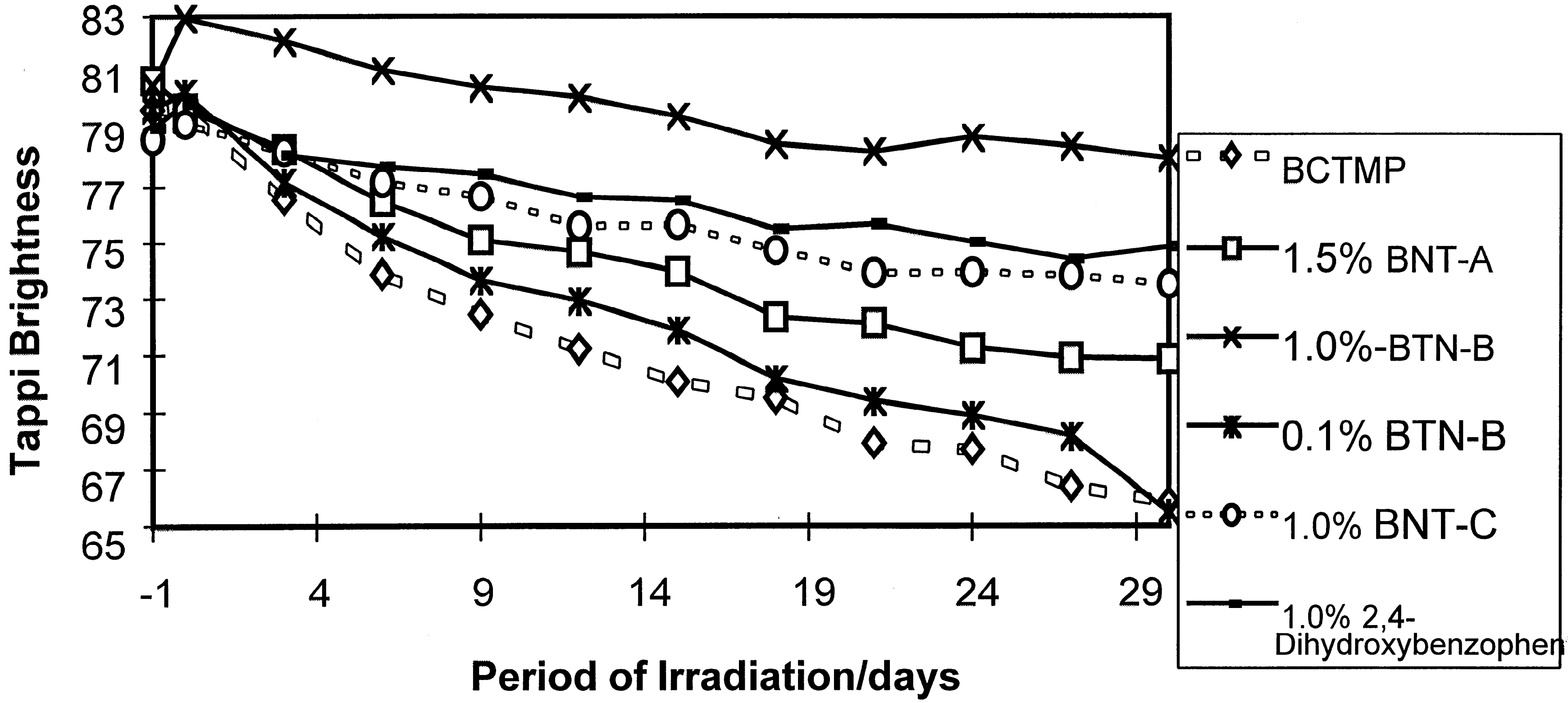


X=H Benzotriazole-B BNT-B
X=Na Benzotriazole-C BNT-C



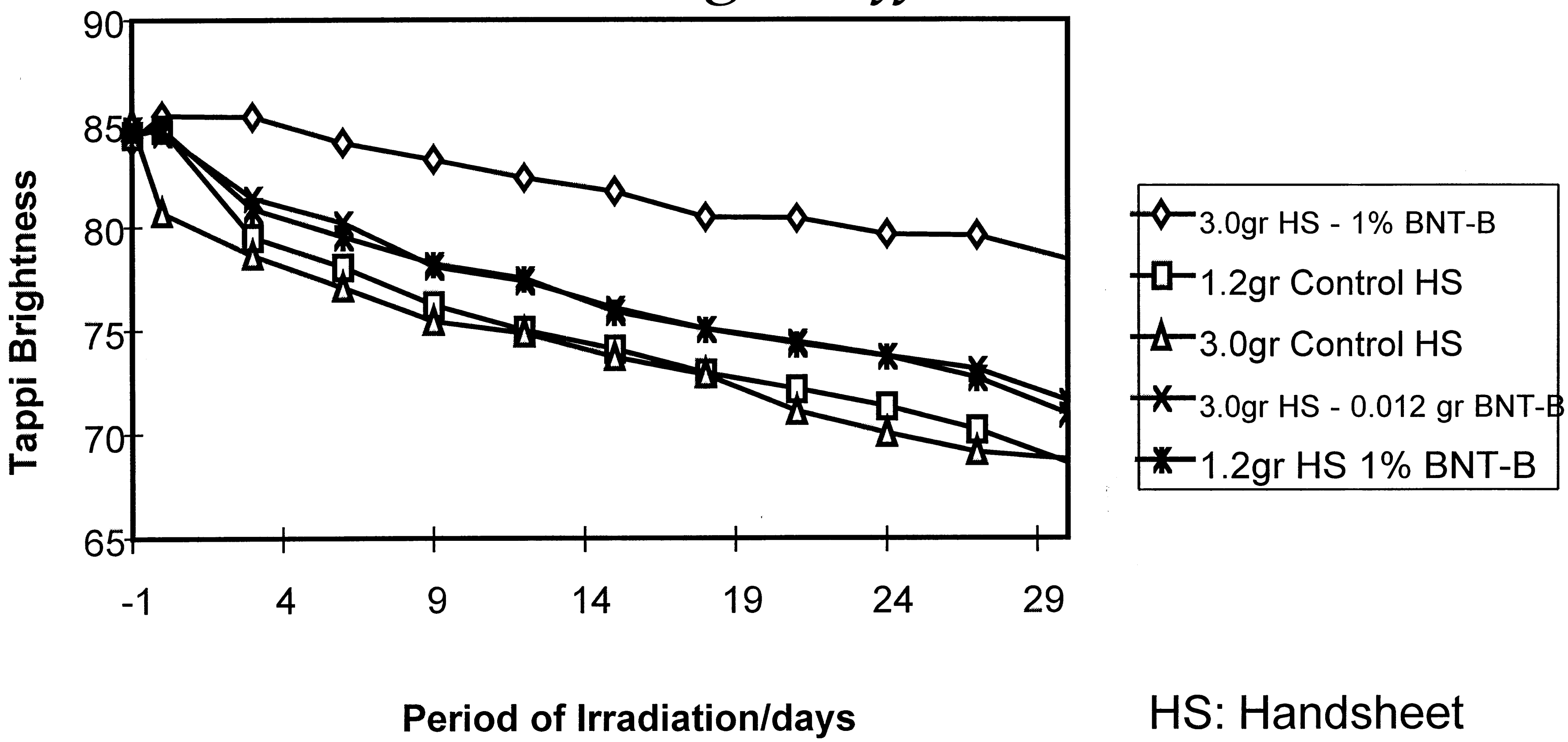
2,4-dihydroxybenzone

F014: Photostabilization Effects for Benzotriazole Derivatives



BTN-B most effective>> Benzophenone

F014: Photostabilization Effects vs. Basis Weight Effects



HS: Handsheet

F014: Photostabilization Effects - Summary

- **Conclusions**

Benzotriazole (H^{+}) photostabilization effect > benzophenone

Although charge of agent important

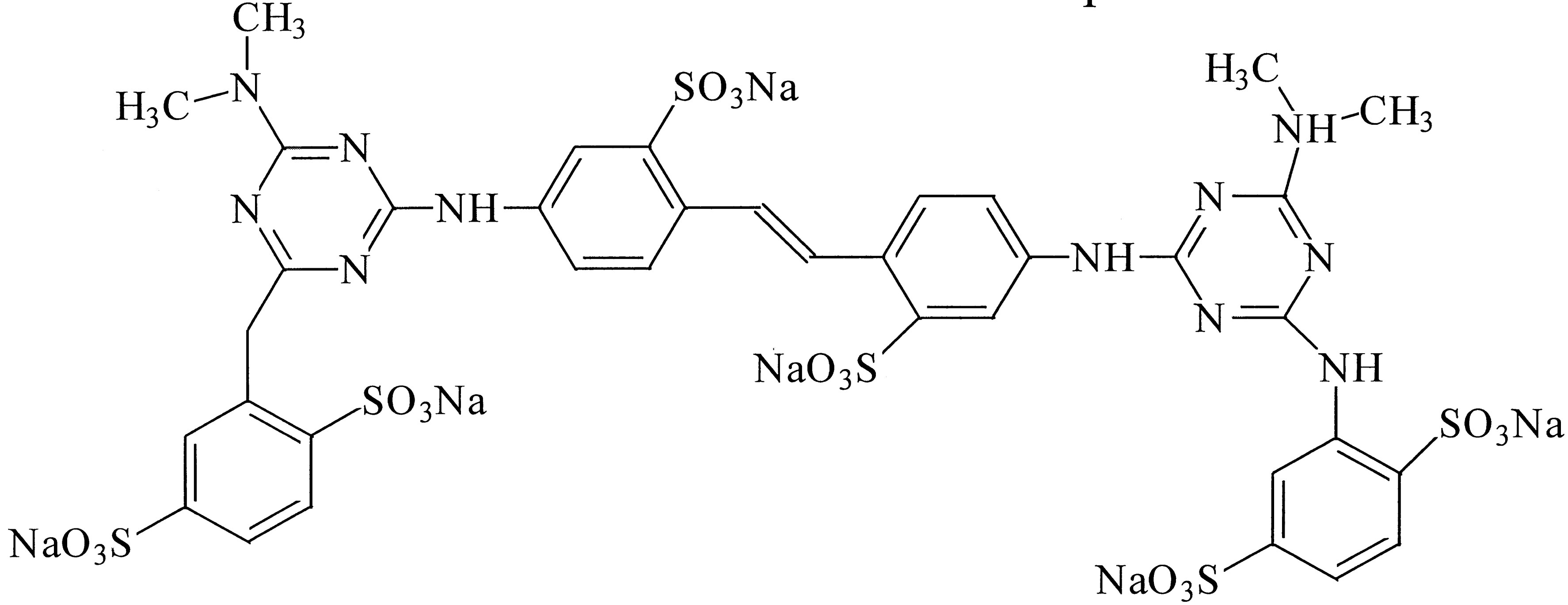
Application/unit area is dominant effect!

F014: FWA Photostabilization Effects - Introduction

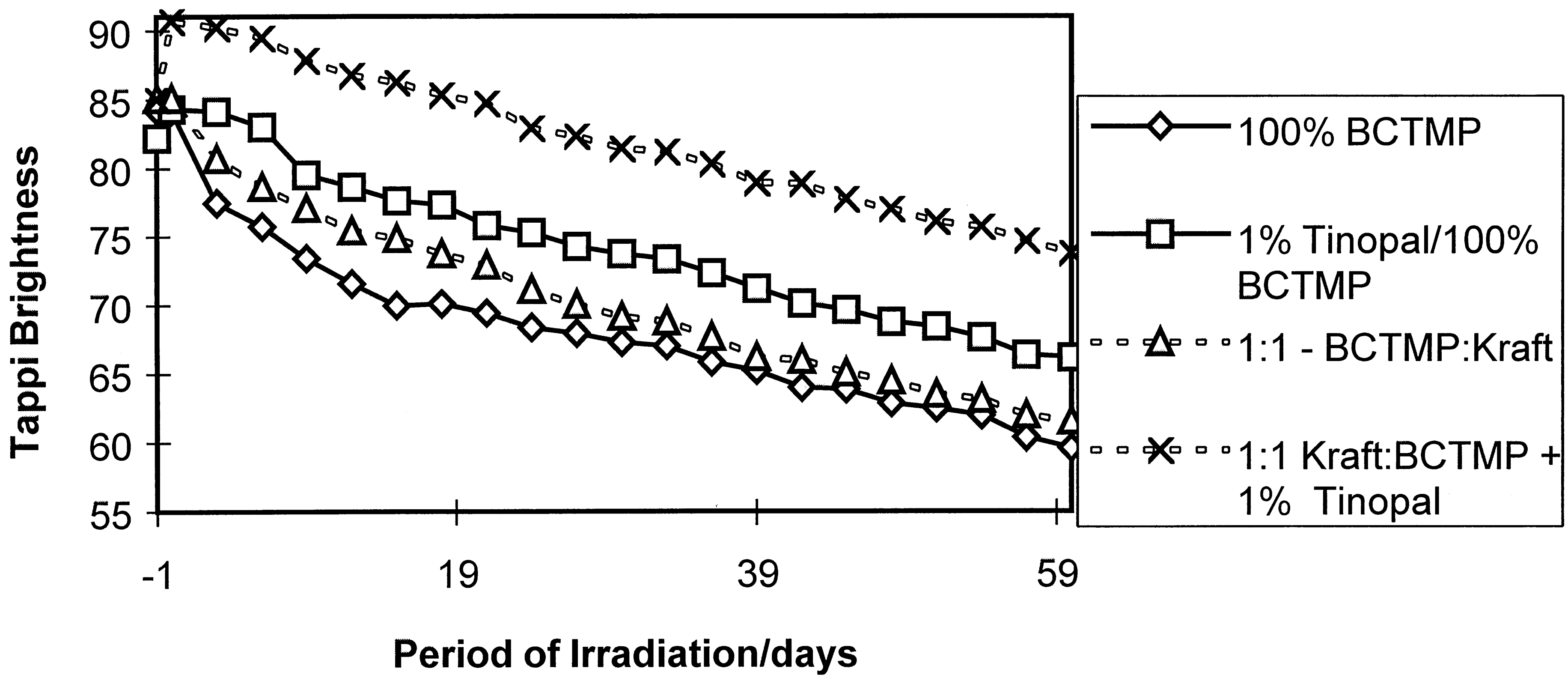
- **Historical Notes**
  - **FWA employed in P&P industry**
  - **Muller reported potential economic benefits for use of FWA for high-brightness CTMPs**
  - **Doshi found no effect for groundwood**
    - **» nature of surface lignin may be important**

F014: FWA Photostabilization Effects - Introduction

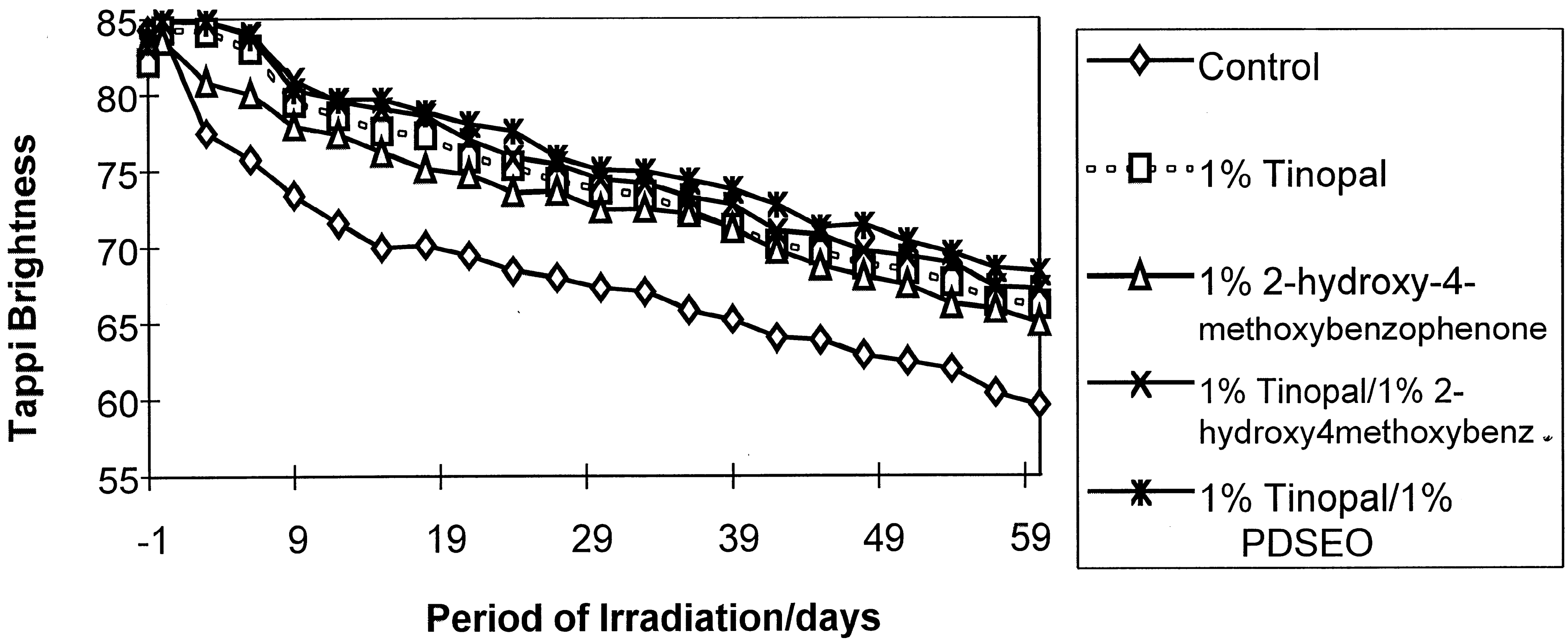
Chemical structure of FWA: Tinopal.



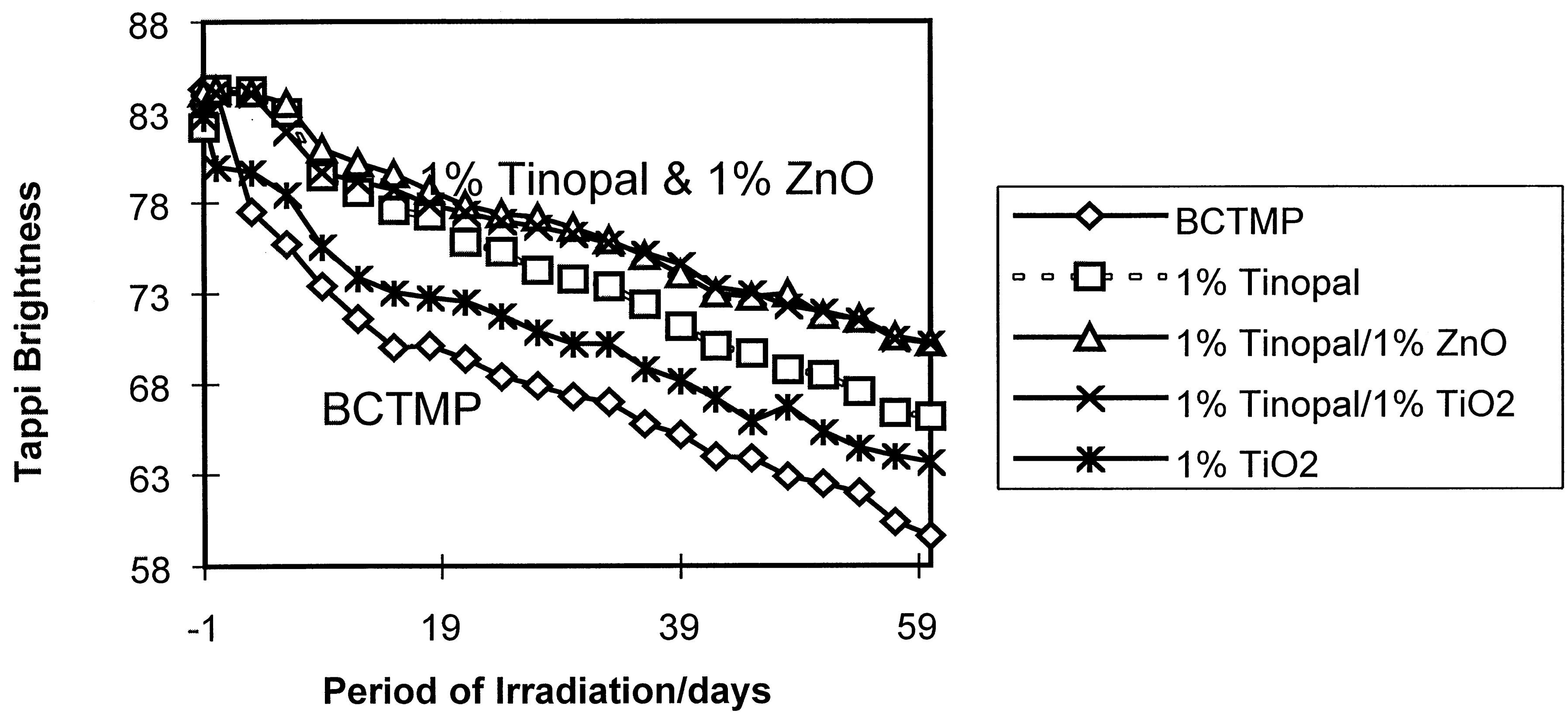
F014: FWA Photostabilization Effects-Results



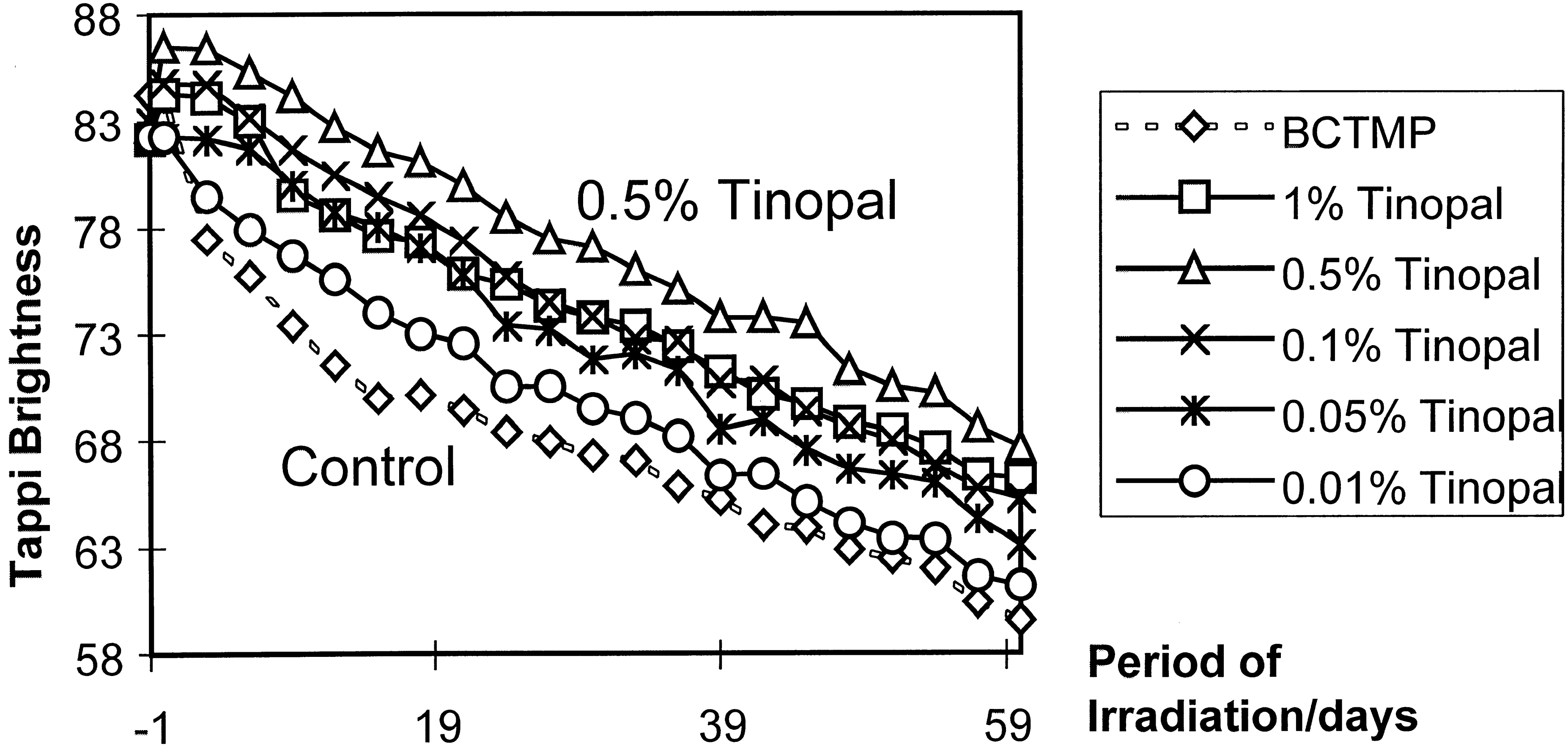
F014: FWA Photostabilization Effects Tinopal & Co-additives Results



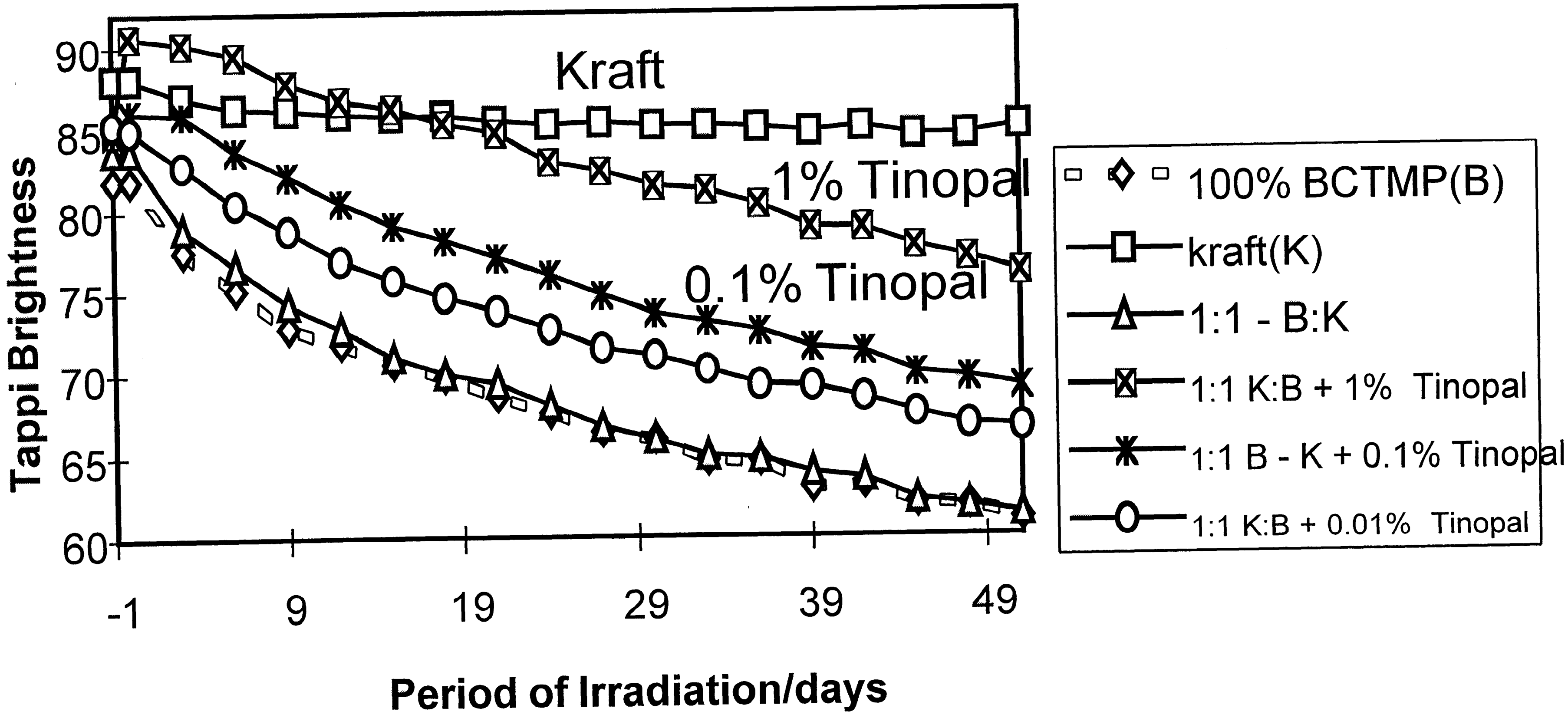
F014: FWA Photostabilization Effects Tinopal & Co-additives Results



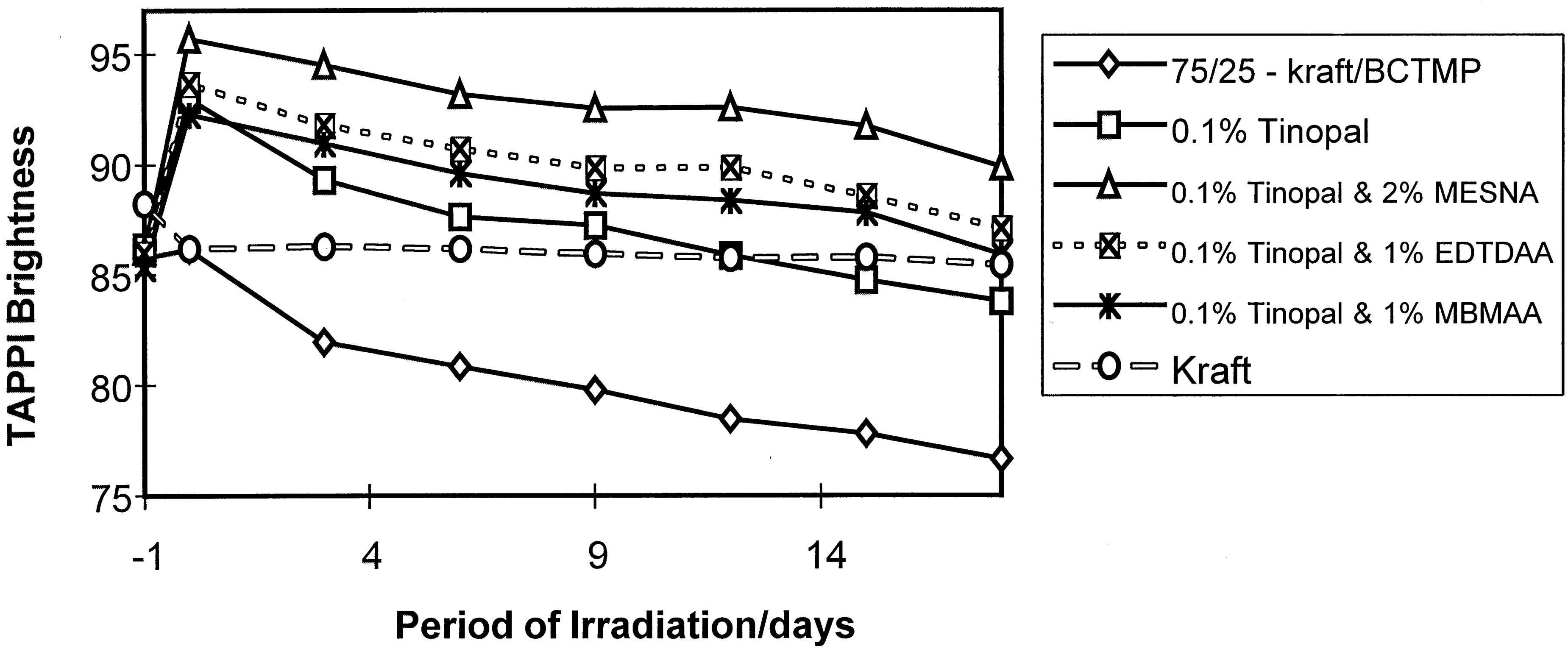
F014: FWA Photostabilization Effects
Tinopal - Charge Effects



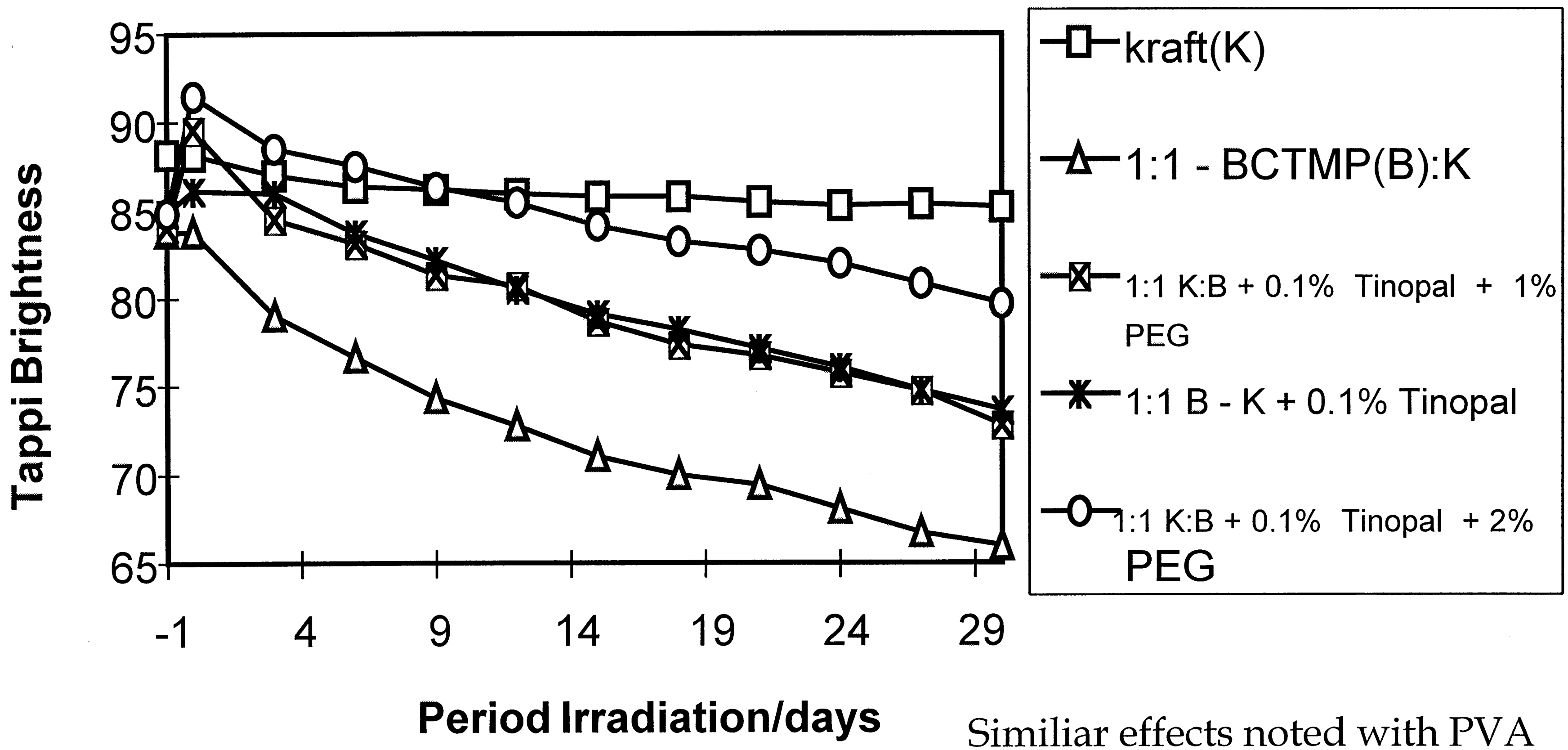
F014: FWA Photostabilization Effects
Tinopal - Furnish Results



F014: FWA Photostabilization Effects Tinopal, Furnish & Co-additives Results



F014: FWA Photostabilization Effects Tinopal, & Carrier Additive Results

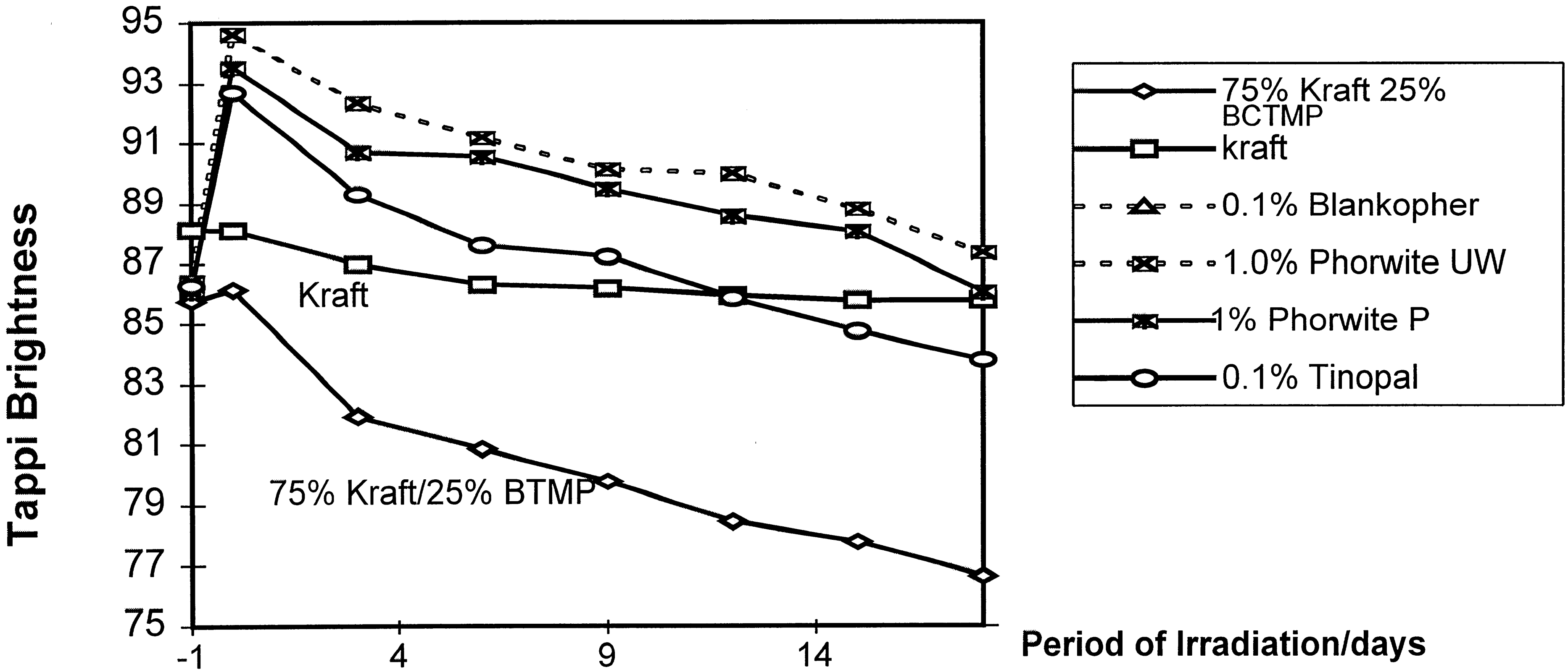


Similiar effects noted with PVA

F014: Tinopal Photostabilization Effects

- Tinopal application maintains +85 Tappi Brightness for 8 - 12 days of continuous light exposure
- Use of radical scavenger, ZnO/TiO_2, or carrier molecule extends photostabilization effect
- UV-absorber are antagonist

F014: Alternative FWAs Applied on Kraft/BCTMP - Results



F014: Conclusions

- **FWA provided some of the most effective photostabilization effects reported.**
- **Additives work well other photostabilization agents**
- **Photostabilization effects varies with specific FWA**

F014: Future Studies

- Optimize FWA & co-additives
- Investigate failure mechanisms of FWA
- Examine optical properties

- Commercial studies

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